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A Study on Perception of Internal Juncture in Japanese

Katsumasa SHIMIZU and Masatake DANTSUJI

I. Introduction

The purpose of the present study is mainly to examine perceptual cues of internal juncture (hereinafter as plus juncture) in Japanese[1]. Plus juncture has a function to divide the sound stream into syntactically meaningful units, and is considered to be a functional entity in various levels of Japanese. We made spectrographic analysis of two contrastive phrases involving plus juncture and carried out identification tests of juncture perception using natural and synthetic speech sounds to find out what perceptual cues are in terms of acoustic grounds and how they are correlated with one another. We would like to examine the results of these experiments in terms of recognizing "words" in the stream of speech sounds and to examine the acoustic-phonetic status of plus juncture.

Much has been reported about acoustic and phonetic characteristics of junctures and syllable structure in English, and several segmental cues have been generally recognized to indicate the junctures and word boundaries (Lehiste, 1960; Trager, 1962; Hartvigson, 1965; Hoard, 1966; Christie, 1974; Nakatani & Dukes, 1977). Among these, Lehiste (1960) presents a comprehensive study of acoustic characteristics on internal open juncture in English and shows several segmental cues to indicate the presence of the juncture[2]. On the other hand, the study on the perceptual cues of junctures in Japanese is quite limited in number of literature and it can be said that it is still less clear what perceptual cues are and how they are correlated with one another in dividing the sound stream into words in Japanese.

Japanese is traditionally analyzed as a mora-structured language, consisting of the sequence of either consonant (C) - vowel (V) or vowel alone or mora nasal. The mora is considered to function as the unit for prosodic features (McCawley, 1968). The phonetic system does not usually allow consonant clusters in the sequence of segments, except the one of consonant geminate which is called "soku-on".

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1. The term "plus juncture" does not necessarily refer to morpheme boundary in a sense generally accepted, but is used in a relatively broad sense.
2. Lehiste (1960) discussed such allophonic variations as aspiration of stop consonants, duration of consonants and vowels, and glottalization of segments in pre- and post-junctural positions, and mentioned that initial and terminal phrases of bounded sequence are characteristic to juncture.

Therefore, the segment in pre-junctural position is always a vowel, while the one in post-junctural position is a vowel or a consonant. In Japanese phonology, several kinds of junctures are proposed in terms of applicability of phonological rules, but since we are interested in examining perceptual cues, we do not go into theoretical details about kinds and hierarchy of junctures (McCawley, 1968). We think it appropriate to set two kinds of junctures for our purpose; internal and terminal junctures, and we use here the term "internal" in a relatively broad sense[3].

As found in other languages, the same sequence of segments in Japanese, constituting some lexical items, can be understood in several ways depending on whether a juncture occurs and where it occurs. For example, /kane o kure/ "Give me (some) money!" and /kane okure/ "Send me (some) money!" indicate that the presence or absence of plus juncture between /o/ and /kure/ distinguishes two meanings from each other, and in many cases the presence affects the durational difference of phrases. We usually hear the difference between two phrases mentioned above, even out of context, and, there must be some perceptual cues to distinguish them. It seems that there are generally two kinds of determining factors to indicate the presence of plus juncture. One is allophonic variations of individual segments which precede or follow it, the other being prosodic factors, whose overall effect of domain is beyond the scope of an individual segment. Little has been studied how these two factors are correlated to each other in identifying plus juncture and which of the factors is dominant in Japanese.

One of the studies related to acoustic characteristics on plus juncture in Japanese is Han (1962). She examined them based on spectrographic analysis of the paired phrases. She drew a conclusion from the analysis that the presence of plus juncture in Japanese can be signalled by glottal constriction between vowel and vowel (or consonant), aspiration of initial voiceless consonants, devoicing of high vowels /i, u/ before voiced consonants, and nonassimilation of syllabic nasals. Han attempted to capture the phenomena of plus juncture as allophonic variations of individual segments in pre- or post-junctural positions but gave little attention to prosodic factors in identifying it. It is plausible to characterize the junctural phenomena in terms of variations of individual segments, but we should consider some prosodic features in a more extended domain of phonetic unit, since pitch in Japanese expresses some characteristics of its accentual system in the sound stream.

The present study includes the experiments of identification of two contrastive phrases of the same sequence taken from natural speech sounds, spectrographic analysis of the contrastive phrases, and identification tests of synthetic speech sounds of /i i e/. Synthetic speech sounds were prepared to examine how such acoustic factors as fundamental frequency and duration affect juncture perception. Test

3. McCawley lists up several kinds of boundaries in Japanese: major phrase boundary @, minor phrase boundary %, and word boundary #. Internal juncture here is considered to refer to the above boundaries.

word /i i e/ in Japanese can be understood in two different ways; negative response "No" and "good picture", depending on the presence or absence of plus juncture and overall pitch pattern.

II. The listening experiment by natural speech sounds

A listening test was designed to examine how phonetic differences between two contrastive phrases of the same sequence were related to the one in meaning. Twenty pairs of contrastive phrases were prepared from the corpus of recorded materials. Two native speakers of Japanese (N. Y., male; Y. H., female) who identified themselves as a speaker of Nagoya dialect recorded materials, and minimal pairs of contrastive phrases were prepared for listening test and the order of a contrastive pair was either retained or reversed in editing. The task of subjects in listening

Table 1. Results of the listening test.

Pair		Percentage of the pair correctly identified for informants NY and YH	
		NY	YH
1. o mo siroi "The tail is white, too."	omosiroi "It's interesting."	100.0%	100.0%
2. iie negative response "No"	ii e "good picture"	97.2	97.2
3. kuruma de "by vehicle"	kuru made "until (one) comes"	100.0	100.0
4. kane o kure "Give me (some) money!"	kane okure "Send me (some) money!"	91.7	58.3
5. akakatta "(It) has been red."	aka katta "red (group) won."	97.2	100.0
6. garasukida "It's quite vacant."	gara sukida "I like the pattern of (cloth)."	91.7	16.7
7. aoi ta "green (rice) field"	ao-ita [4] "blue board"	97.2	97.2
8. nagai si "lengthy poem"	naga-isi "long rock"	100.0	97.2
9. sato-oya "foster parents"	satooya "sugar store"	77.8	80.6
10. aoi to "blue door"	ao-ito "blue string"	100.0	97.2
11. kare no miyori "his relatives"	kare nomi yori "rather than himself alone"	97.2	83.3
12. kasa naika "Isn't there an umbrella?"	kasanaika "Won't you lend me (something)?"	100.0	100.0
13. su-uri "vinegar seller"	suuri "mathematical principle"	100.0	100.0
14. nagaimo "yam"	nagai mo "long seaweed"	86.1	94.4
15. kuro-iwa "black rock"	kuroi wa "black ring"	86.1	91.7

4. Hyphen–here is considered to be an internal word boundary. Phonetically it is realized as the constriction at the glottis. In Japanese, the element of glottal constriction is considered to precede "mora" initial vowels.

test was to indicate which of the contrastive pairs occurred first in the answer sheet.

36 native speakers of Japanese in Nagoya dialect area took part in the listening test as a subject. They were students of Nagoya Gakuin Univ. and were majored in economics. They were tested in sound-proofed language laboratory booths of the university.

The results of the listening test for fifteen pairs can be shown in Table 1. The figures represent the percentage of the contrastive phrases correctly identified by the subjects. The results in Table 1 showed a considerably good performance in identifying the contrastive pair. It seems that with the exception of a few phrases, subjects had no difficulty in identifying the pair correctly. In order to examine the perceptual cues for differentiating the contrastive pairs, wide- and narrow-band spectrograms were made of each utterance for the measurements of duration, pitch pattern and amplitude. The durational measurements were made for consonant closure, voice onset time and vowels.

2.1 Stop Closure Duration

We examined whether stop closure duration was susceptive to the presence of plus juncture. Stop closure duration can be defined as the one for the maximum constriction for the stop and is evidenced by an abrupt drop in the amplitude and by release burst.

In Table 2, we find that stop closure duration in the post-junctural position was noticeably longer than that in non-junctural position. It seems that the increase of closure duration may signal the presence of plus juncture and may be one of the perceptual cues to differentiate the contrastive phrases. We also find that closure duration of /t/ is longer than that of /k/, and this seems to be due to the difference in oral cavity size and in oral constriction between two segments.

2.2 Voice Onset Time (VOT)

VOT can be defined as the duration of the gap between the release of stop consonant and the onset of glottal pulsing for the following vowel. We examined whether VOT of stop consonants varies depending on the presence or absence of

Table 2. Stop closure duration (msec).

Pair		Informant	Type of Consonant	Stop Closure	
				Post-junc.	Non-junc.
1. a) aoi t̲a	b) ao-i̲ta	NY	/t/	77 msec	54 msec
"green (rice) field"	"blue board"	YH	/t/	84	46
2. a) aoi t̲o	b) ao-i̲to	NY	/t/	105	75
"blue door"	"blue string"	YH	/t/	120	84
3. a) akai t̲o	b) aka-i̲to	NY	/t/	120	99
"red door"	"red string"	YH	/t/	86	53
4. a) aka k̲atta	b) akak̲atta	NY	/k/	44	25
"red (group) won."	"(It) has been red."	YH	/k/	66	21
5. a) kane o k̲ure	b) kane ok̲ure	NY	/k/	57	56
"Give me (some) money!"	"Send me (some) money!"	YH	/k/	73	65

Table 3. Voice onset time of voiceless stop consonants (msec).

Pair		Informant	Type of Consonant	Voice Onset Time	
				Post-junc.	Non-junc.
1. a) aoi ta	b) ao-ita	NY	/t/	15 msec	14 msec
"green (rice) field"	"blue board"	YH	/t/	21	37
2. a) aoi to	b) ao-ito	NY	/t/	16	16
"blue door"	"blue string"	YH	/t/	16	15
3. a) akai to	b) aka-ito	NY	/t/	16	14
"red door"	"red string"	YH	/t/	—	—
4. a) aka katta	b) akakatta	NY	/k/	31	33
"red (group) won."	"(It) has been red."	YH	/k/	33	25
5. a) kane o kure	b) kane okure	NY	/k/	25	23
"Give me (some) money!"	"Send me (some) money!"	YH	/k/	33	32

plus juncture. In Table 3 were presented VOT values of /t/ and /k/ in post- and non-junctural positions.

In examining VOT values of /t/ and /k/, we find that there was no significant difference in the values whether the consonants were in the post-junctural position or non-junctural position, except the utterance of /aoi ta – ao-ita/ by YH, and, therefore, the presence of plus juncture had little effects on VOT values of the consonants. It can be said that voiceless consonants in Japanese are not noticeably aspirated even if they are in post-junctural position[5]. It is of interest because aspiration is not significant in identifying plus juncture in Japanese, though it is one of the dominant factors in English.

2.3 Vowel Duration

The question was whether there was a significant difference in vowel duration in a pre-junctural position as opposed to non-junctural position. Vowel duration was defined as the interval from apparent onset of the lower formants to the cessation of the formants. The cessation of the lower formants in a pre-junctural position was evidenced by an abrupt drop in amplitude of all formants. In Table 4, we present vowel duration in msec in pre- and non-junctural positions.

Examining the vowel duration, we find that it varies depending on the differences of phonetic circumstances, and vowel /a/ in utterance of 2 was the longest before the voiceless sibilant /s/. The duration in a pre-junctural position was longer in utterances of 2 (by NY) and 3, while it was shorter in utterances of 1 (by YH) and 5 than that of non-junctural position. These differences were less significant, and it does not seem that the presence of plus juncture gave consistent effects on vowel duration, and the duration was less susceptible to the presence or absence of plus juncture. However, the spectrographic data which was relevant to the vowel duration in a pre-junctural position was limited, and we think it necessary to have further

5. In Shimizu (1979), VOT values for /ta/ and /ka/ in Japanese were examined. The values are 22 msec for /ta/ and 40 msec for /ka/ in average, and the degree of aspiration is not so strong in Japanese.

Table 4. Vowel duration in pre- and non-junctural positions.

Pair		Informant	Type of Vowel	Vowel Duration	
				Pre-junc.	Non-junc.
1. a) kasa naika	b) kasanaika	NY	/a/	57 msec	52 msec
"Isn't there an umbrella?"	"Won't you lend me (something)?"	YH	/a/	70	80
2. a) gara sukida	b) garasukida	NY	/a/	230	160
"I like the pattern of (cloth)."	"It's quite vacant."	YH	/a/	205	201
3) a) aka katta	b) akakatta	NY	/a/	73	66
"red (group) won."	"(It) has been red."	YH	/a/	78	66
4. a) isu no se	b) isu nose	NY	/o/	78	78
"the back of a chair"	"the stand for a chair"	YH	/o/	112	113
5. a) kare no miyori	b) kare nomi yori	NY	/o/	70	75
"his relatives"	"rather than himself alone"	YH	/o/	92	97

data to substantiate the effect of plus juncture on the duration.

2.4 Fundamental Frequency Pattern (Fo pattern)

Japanese is characterized as having a pitch accent system and the system is acoustically realized by Fo pattern. It is known that pitch patterns play a role in distinguishing the phrases of the same sequence. We examined whether the presence of plus juncture could be shown by the changes of Fo patterns. In Table 5 we pre-

Table 5. Fundamental frequency patterns of contrastive phrases.

Informant	Pair	
	1. a) "The tail is white, too."	b) "It's interesting."
NY	o mo siroi	omosiroi
YH	o mo siroi	omosiroi
	2. a) "blue door"	b) "blue string"
NY	aoi to	ao-ito
YH	aoi to	ao-ito
	3. a) "Isn't there an umbrella?"	b) "Won't you lend me (something)?"
NY	kasa naika	kasanaika
YH	kasa naika	kasanaika
	4. a) "good picture"	b) negative response "No"
NY	ii e	iie
YH	ii e	iie
	5. a) "red (group) won."	b) "(It) has been red."
NY	aka katta	akakatta
YH	aka katta	akakatta

sent Fo patterns based on the analysis of narrow-band spectrograms of the contrastive pairs which were identified with a high rate of accuracy (97.2% and up).

From Table 5, it is evident that Fo patterns have some correlation with plus juncture, and the presence can be signalled by falling in a pre-junctural position and rising or levelling in a post-junctural one. Fo patterns tend to change consistently in junctural position and have prominent effects in identifying plus juncture.

In parallel with Fo patterns, we examined the amplitude pattern of the above phrases, and the overall examination showed that it was falling in a pre-junctural position and was rising in a post-junctural position. Since the generation of Fo is attributed to the vibration of vocal folds and the one of amplitude to articulatory force, there exists some correlation between Fo and amplitude, and, therefore, the falling-rising pattern of amplitude in juncture may be a predicted one.

III. The listening experiments by synthetic speech sounds

To examine perceptual cues of plus juncture in Japanese, we analyzed the wide- and narrow-band spectrograms of two contrastive phrases in natural speech sounds, and it appears that possible cues of plus juncture were such prosodic factors as Fo pattern, amplitude, and stop closure duration rather than allophonic variations of segments. Although there might be some other cues which might not appear in spectrograms, it seems that prosodic cues are more influential than segmental cues for juncture perception in Japanese. In order to substantiate their effects, we carried out identification tests by using synthetic speech sounds by controlling duration of pause and Fo patterns.

Test word was /i i e/. As mentioned previously, the word is understood in two ways depending on the presence or absence of plus juncture and overall pitch pattern; one is negative response "No" and the other is "good picture". The test stimuli were all in the form of /i i e/, and three possible cues were examined; the duration of pause between the second /i/ and the final /e/, Fo patterns of the second /i/ and the final /e/. These stimuli were synthesized by the terminal analog

Table 6. Frequencies of five formants and fundamental frequency of /i i e/.

Formant	/i/	/i/	/e/	Bandwidth
F_5	4, 500 Hz	4, 500 Hz	4, 500 Hz	281 Hz
F_4	3, 500	3, 500	3, 500	175
F_3	3, 000	3, 000	2, 550	200
F_2	2, 100	2, 100	2, 100	130
F_1	300	300	510	80
F_0	130	130	130	

N. B. Intensity was kept constant through three vowels. Duration of onset and offset of each vowel was 50 msec each. Duration of steady state portion of each vowel was 200 msec. Fo of the second /i/ and the final /e/ is a variable in experiments 3.2 and 3.3.

synthesizer at Kyoto Univ[6]. Each vowel was a five-formant synthetic speech sound, and the detailed acoustic features of the test word /i i e/ are shown in Table 6.

3.1 Experiment for Duration of Pause

This experiment was designed to examine whether duration of pause functions in identifying the presence of plus juncture. The test word was /i i e/ whose acoustic details were mentioned in Table 6. Test continuum consisted of 6 test word stimuli with varying duration of pause between the second /i/ and the final /e/. The duration was varied with 0, 150, 200, 250, 300, and 400 msec each. Each of the test words was presented 5 times, and total 30 test words were presented to the subjects in a randomized order at a comfortable listening level.

The test was carried out in a rather small number of subjects. They were 6 phonetically untrained junior students of Nagoya Gakuin Univ. They had normal hearing ability and identified themselves as a speaker of Nagoya dialect. They were instructed to indicate in the answer sheet whether the test word belonged to /iie/ of negative response "No" or /ii e/ of "good picture".

The results of the identification test can be presented in curves of Figure 1. They indicate that the duration of pause between the second /i/ and the final /e/ functions

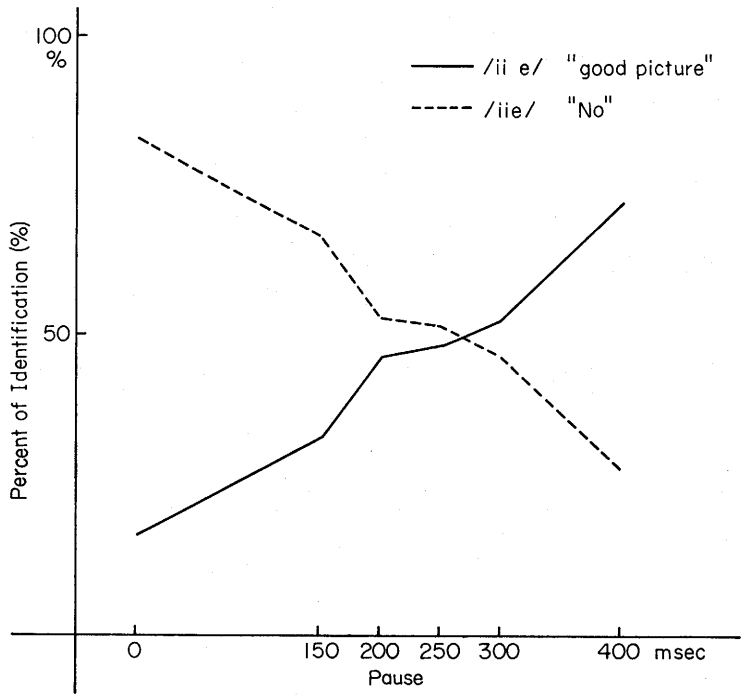


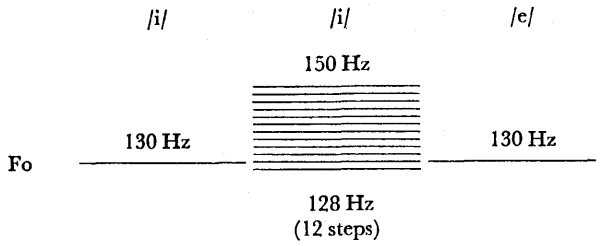
Fig. 1. Effects of duration of pause on juncture perception. The solid line indicates the identification of /ii e/ of "good picture" and the dotted line the identification of /iie/ of "No".

6. The synthetic speech sounds were prepared by Melcom 70 at the Dept. of Information Science of Kyoto University.

as a perceptual cue to distinguish two meanings of /i i e/. Shorter duration of pause gave a greater number of "No" responses, while longer duration of puase did a greater number of "good picture" responses. The crossing point of two responses was in the range from 250 to 300 msec of duration of pause, and this may imply that the presence of plus juncture requires a duration of pause longer than 250 msec. As seen in the lexical structure, /iie/ of negative response "No" is supposed to have no juncture in it. However, as far as pause duration as a perceptual cue is concerned, the results of the test show that /iie/ for "No" responses is able to have some allowance of pause whose duration is shorter than 250 msec. Even if there exists a pause between the two segments, shorter duration is categorized as having no juncture.

3.2 Experiment for Fundamental Frequency of the Second /i/

In this experiment we examined the effect of fundamental frequency (Fo) of the second /i/ on juncture perception. Acoustic details of test words were the same as described in Table 6, except Fo of the second /i/. Twelve test words of /i i e/ were prepared with varying Fo of the second /i/ from 128 to 150 Hz with 2 Hz step. Fo pattern of /i i e/ can be schematically shown as follows:



Similar procedure was taken in this experiment as in experiment 3.1. Each of the twelve test words was presented 9 times, totalling 108 test words. They were presented in a randomized order at a comfortable listening level. Subjects were instructed to identify either /iie/ of negative response "No" or /ii e/ of "good picture" in the answer sheet.

The subjects for this experiment were from two dialect groups; Nagoya and Osaka dialect areas. Subjects in Nagoya area were 47 students of Nagoya Gakuin Univ., while those of Osaka area were 28 students of Kooka Women's University. Both groups were phonetically naive and were given some trials before the test.

The results of this experiment for two dialect groups were shown in the curves of Figures 2a and 2b. It is clear that there is a notable difference in the identification curves of /i i e/ between two dialect groups. For those speakers of Osaka area, they gave more responses belonging to "No" when Fo was in the range from 128 to 132 Hz. As Fo went up, more responses belonging to "good picture" were obtained. The crossing point lay in the Fo domain of around 138 Hz. On the other hand, for those speakers of Nagoya area, almost 70% responses of "No" were observed when Fo was above 132 Hz, and the crossing point lay at around 130 Hz. This difference

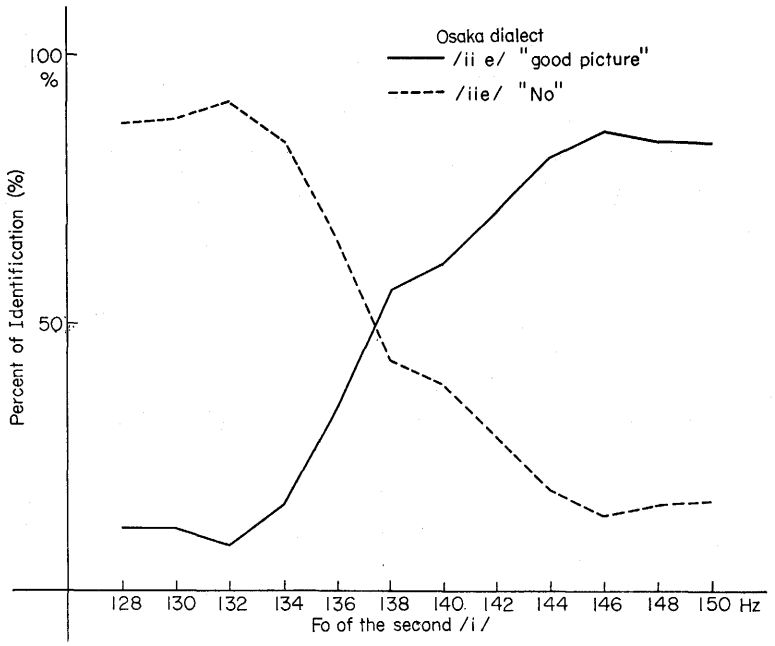


Fig. 2a.

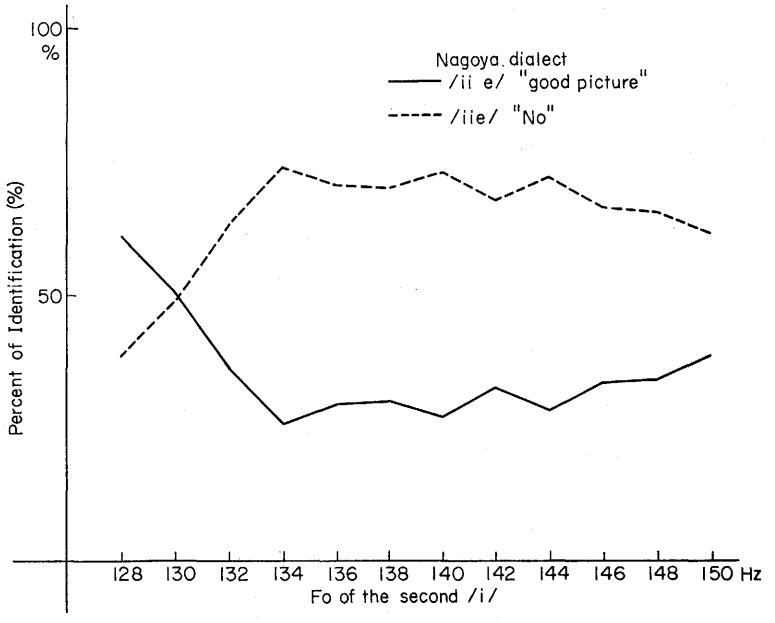


Fig. 2b.

Fig. 2. Effects of fundamental frequency of the second /i/. The solid line indicates the identification of /ii e/ of "good picture" and the dotted line the identification of /iie/ of "No".

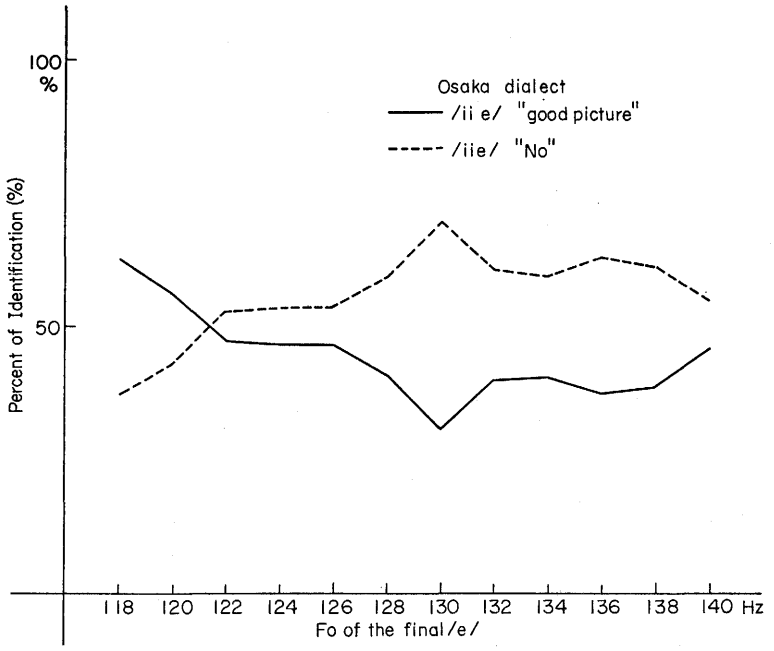


Fig. 3a.

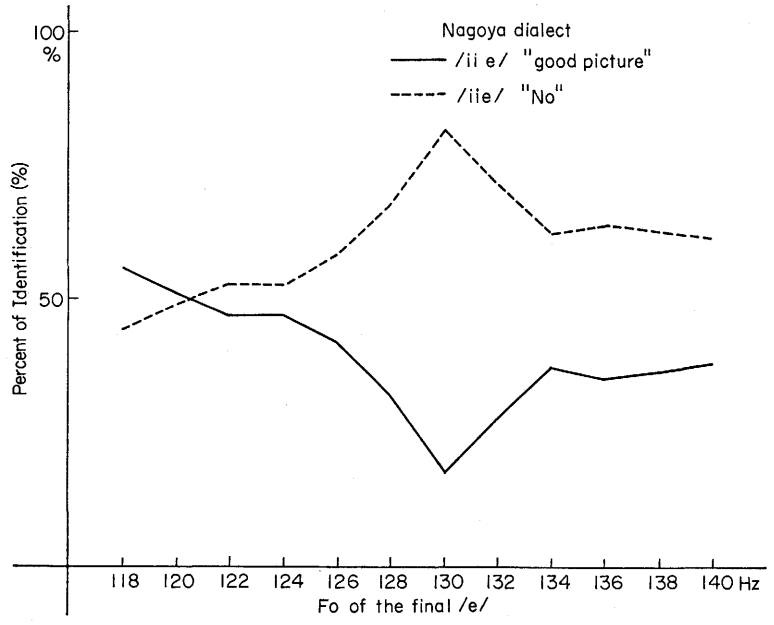


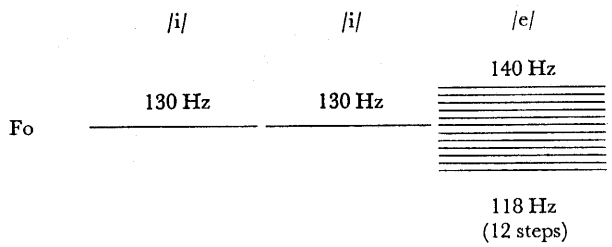
Fig. 3b.

Fig. 3. Effects of fundamental frequency of the final /e/. The solid line indicates the identification of /ii e/ of "good picture" and the dotted line the identification of /iie/ of "No".

indicates that in Osaka area there exists a contrastive pitch pattern of the second /i/ in distinguishing two meanings of /i i e/, while in Nagoya area there is no such contrast of pitch pattern.

3.3 Experiment for Fundamental Frequency of Final /e/

This experiment was designed to examine the effect of Fo of the final /e/ for juncture perception. As in the same way mentioned in 3.2, twelve test words of /i i e/ were prepared with varying Fo of the final /e/ from 118 to 140 Hz with 2 Hz step. Acousitc details of the test words were the same as in Table 6, and Fo pattern of /i i e/ can be schematically shown as follows:



The experimental procedure was the same as in 3.1 and 3.2. Each of the twelve test words was presented 8 times, totalling 96 test words. They were presented in a randomized order at a comfortable listening level. The task of subjects was to identify whether the test words belong to either negative response "No" or "good picture".

As in experiment 3.2, the subjects for this experiment were from two dialect groups; Nagoya and Osaka dialect areas. Subjects in Nagoya area were 51 students of Nagoya Gakuin Univ., while those of Osaka area were 27 students of Kooka Women's Univ. Both groups were phonetically naive and were given some trials before the test.

The results of this experiment were shown in the curves of Figures 3a and 3b. The curves in both figures did not show any typical identification mode as predicted in categorical or continuous pattern of identification. The rate for "good picture" was not so significant even when Fo of the final /e/ went up. Both groups showed a similar pattern of identification; the crossing point was between 120 and 122 Hz, and at the frequency of 130 Hz, the responses for "No" were maximized, while those for "good picture" were minimized. These results indicate that Fo of /e/ in /i i e/ was not a decisive factor in distinguishing two meanings of /i i e/.

IV. DISCUSSION

In this discussion we would like to examine the results of identification tests by using natural and synthetic speech sounds, their spectrographic analysis, and their implications in identifying the presence of plus juncture in Japanese.

In the listening test of contrastive phrases of natural speech sounds, we obtained

a high degree of accuracy in identifying them. From the spectrographic analysis, we found that duration of stop closure, Fo pattern and amplitude pattern had consistent and significant effects on the presence of plus juncture, while vowel duration and voice onset time of stop consonants did not. Since such cues as Fo and amplitude can be categorized as prosodic factors, it is possible to suggest that such factors carry information to indicate the presence of plus juncture in Japanese. This might be an expected result from the fact that Japanese has characteristic prosodic structures which are based on pitch contrast of high-low pattern. On the other hand, there were no significant effects on vowel duration and voice onset time. Especially it was shown that the degree of aspiration was generally weak in Japanese, even in word-initial position. It is interesting to note that allophonic variation between aspirated and unaspirated stops does not serve to cue the presence of plus juncture. But this does not mean that other allophonic variations are totally irrelevant for juncture perception. As Han (1962) mentioned, we can point out that some variations such as glottal constriction seem to be significant, though we did not examine them in detail here. Each language has its characteristic articulatory-acoustic cues for the presence of juncture, and some cues which are considered to be prominent in one language may not be in other languages. Aspiration of stops is considered to be one of the prominent cues in English, but it is not in Japanese.

Among two major factors of prosodic and segmental cues, it appears that prosodic ones are more significant in identifying the location of plus juncture, and it is necessary to examine which cues among Fo, amplitude and duration are strong and weak. We analyzed the spectrographic data of the contrastive pairs whose degree of accuracy was quite high, and we found that the fall-rise contour of Fo was prominent in junctural position. Since Fo and amplitude are correlated with each other in the physical efforts of speech production, the change of Fo is often accompanied with the one of amplitude pattern. In examining such prosodic factors, it is possible to assert that Fo does serve to cue the plus juncture as a strong and significant factor, and amplitude and duration of stop closure also serve to cue it.

In order to examine the correlation of prosodic factors with juncture perception, we carried out the identification tests using the continuum of synthetic speech sounds /i i e/. The experimental results suggest that duration of pause between the second /i/ and the final /e/ and Fo of the second /i/ serve to distinguish two meanings of /i i e/ and to cue the presence of plus juncture between them. The subjects in the experiments were from two dialect areas, and it was shown that two groups have distinct characteristics in identifying two meanings of /i i e/. Based on the narrow-band spectrograms, we examined Fo patterns for two meanings in natural speech sounds, and the accent patterns in two dialect areas can be shown as follows:

	"Good picture"	Negative response "No"
Osaka area	i | i _ e	i i | e
Nagoya area	i | i e	i i | e

In Osaka dialect, there exist two contrasts in pitch pattern of the second /i/ and the final /e/; for "good picture" the second /i/ is high-pitched and for "No" the final /e/ is high-pitched, being the others low-pitched. In Nagoya dialect, on the other hand, pitch contrast exists in the first /i/ and the final /e/; for "good picture" the first /i/ is high-pitched and for "No" the final /e/ is high-pitched, being the others low-pitched. That is, in Osaka dialect, high-low pitch contrast of the second /i/ serves to distinguish two meanings, but not in Nagoya dialect. This fact could be confirmed by the results of experiment 3.2; Fo of the second /i/ functions to cue the presence of plus juncture in Osaka dialect but not in Nagoya dialect. Furthermore, in spite of the fact that the final /e/ also functions to distinguish two meanings in each dialect, the effect was not confirmed in experiment 3.3 in which Fo of the final /e/ was varied. This implies that even if each mora has a characteristic pitch pattern to cue the difference in meaning, it has a different degree of function in exerting the effect. In the case of /i i e/, the second /i/ is more influential to distinguish two meanings than the final /e/.

V. SUMMARY

From the present experiments on internal juncture in Japanese, it may be concluded that prosodic factors are more prominent than allophonic variations of the segments for juncture perception. Especially, the fall-rise contour of Fo is pronounced in pre- and post-junctural positions. Amplitude and duration of stop closure are also significant as a perceptual cue for juncture, and the duration of stop closure was increased in post-junctural position. Secondly, there was no significant difference in VOT values of stop consonants in junctural position as opposed to those in non-junctural position. Although the effects of juncture on aspiration of stop consonants or vowel duration were not significantly found, this does not mean that allophonic variations are irrelevant. Since the data on them is limited in the present study, we need further experiments to examine the effects on other allophonic variations of segments. Finally, from the identification tests by using synthetic speech sounds, the effects of pause and Fo patterns were confirmed. Each dialect has some characteristic Fo patterns to distinguish contrastive phrases, but there are cases in which each mora in contrast has a different degree of effects on pitch perception of the phrases.

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